Energy conservation opportunities: Sugar industry in Iran

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Abstract- Energy consumption and its impact on the efficiency and environmental issues has become of great importance recently. Sugar is the main energy consumer among food product industry and has an old technology. Sugar production has been one of the most energy intensive industries in Iran during recent years since its technological infrastructure is poor and needs to be promoted. Energy intensity and the amount of energy consumption of sugar factories have a critical situation. Sugar factories can be categorized as three sections depend on different available raw materials such as beet, cane, and raw sugar. This industry is the 2nd oldest industry in country that produces 1250000 ton sugar in 2003. Energy intensity of Iranian factories is 27 GJ/ton while this index is 19.27 GJ/ton for the average of the world and 11 GJ/ton for developed countries. Comparing the average energy intensity of sugar industry in Iran with the world data, there are 42% saving potential for factories that consume beet as raw material, 6% saving for cane, and 63% for raw sugar in 2002. This study, based on conducting on-site energy audits of 36 factories in Iran during 2001-2004, discovered 2570 terra J/year energy-saving potentials. The main reasons for this gap management problems, old machinery, and old production technology and cane & beet sugar content. In addition there is a large gap in raw sugar refineries between Iran and other countries.
As a result of monitoring manufacturing units in the country, the following significant results achieved for policy makers: supporting of establishment the new higher efficient units, planning conversion the traditional units into industrial ones, introducing new standards and developing much richer sugar content of consuming raw material in producing plants. This paper discusses the present situation of sugar industry from the technological point of view and related indexes, the possible solutions to the industry, possible policies in terms of its current technologies and available standards, the impact of policies in the whole industry situation and the role of policy makers. Saving options have been economically and technologically evaluated and compared.
Key-words: Sugar industry, Iran, energy conservation.

1 Introduction

The industry sector plays a significant role in global energy consumption. Sugar is one of the most energy consuming industries. Since energy production is extensively based on using fossil fuels, the environmental issues will become of great importance. The economical and environmental issues and obligations cause the industry to move toward better design conditions. Therefore, there is a need to pursue a new policy to force producers to undertake energy-efficient practices to establish sustainable production systems without disrupting the natural resources.

Sugar beet is mainly used for human food, livestock feed and in industry. The two main sources of sucrose (sugar) for human consumption are sugar cane and sugar beet. About one fourth of the world's sugar production comes from sugar beet (about 40 million tons in 1999). Sugar content of sugar beet is about 25% higher than that found in sugar cane. Sugar production from sugar beet is more expensive than that of sugar cane. However, due to the financial contributions provided to sugar industry, and some agricultural and social benefits, sugar beet growing is still continuing to increase in many countries. Sugar beet was grown in 51 countries in 2004, with 238 million metric tons of production. The major producers of sugar beet in 2004 were France, the United States, Germany, Russian Federation, Turkey, Ukraine and Poland [1]. Both sugar beet production and sugar industry have a very significant role in Iran's agriculture and agro-industry regarding technological, economical and social development of rural communities.

Efficient use of energy is one of the principal requirements of sustainable industry. Energy use in food industry has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. However, intensive use of energy causes problems threatening public health and environment. Efficient use of energy will minimize environmental problems, prevent destruction of natural resources, and promote sustainable development as an economical production system. Thus, an energy-efficient and environmentally sensitive sugar beet production program can be realized in Iran.

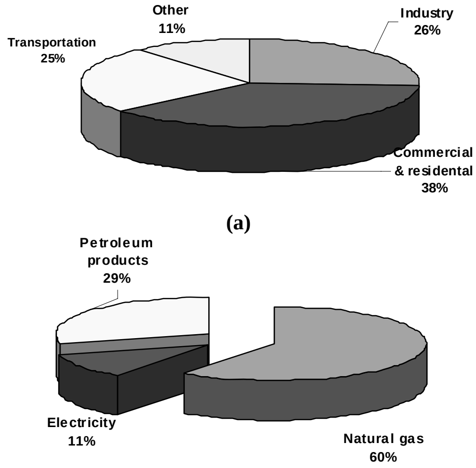
Sugar companies have been mainly involved in environmental problems connected with traditional technology, such as the production of large masses of beet pulp, molasses and carbonation lime, and the consumption of energy and water [2].

Besides concern regarding pollution prevention, one of the issues of critical relevance in the context of sustainability, is the consumption of energy. A massive amount of energy is needed to produce sugar. The excess of energy consumed in the sugar plant above the energy theoretically needed should be lowered as much as possible. The reduction of energy consumption in sugar production usually includes improvements in those energy systems comprising power plants, multiple-stage evaporators and process heating equipment [3]. Environmentally friendly technologies are becoming more and more popular because of increased environmental pollution such as ethanol production process using the fermentation of molasses, one of the main by-products from sugar production [4].

The present paper will study the energy situation in sugar production in Iran and its role in the entire energy system. It reviews the production process available in the country and assets the possibilities to improve the efficiency and save energy based on energy auditing programs in which the basic amount of energy required is calculated roughly and compared to real data available from site-visit with regards to Iranian National Standards. Opportunities from the point of energy- and financial- saving will be chosen in order to promote the energy situation of each factory.

2 Current situation in Iran

26 percent of total energy consumption in Iran is contributed to industrial sector that involves 29% petroleum products, 60% natural gas and 11% electricity (Figures 1).



(b)

Figure 1 Energy consumption in Iran (a), Quantities of different energy carriers using in Iranian Industries (b) (2004) [5]

The main contributors to energy consumption in Iranian industries are shown in Figure 2. As illustrated, Food industry is 5th major consumer and allocates 10% of total industrial energy consumption.

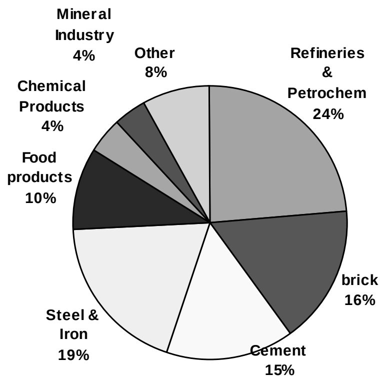


Figure 5 Energy consumption in different industries (005-006) [5]

Food industry is one of the old industries in Iran and has 8.11% of total no. of industrialized units and 16 % of total investment and 15% of employment of industry sector in 2003. This include sugar, conserve, beverages, edible-oil, dairy, ….

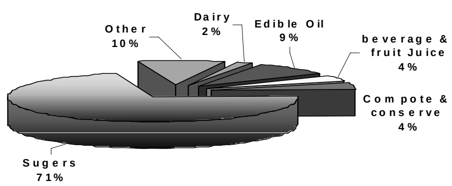


Figure 3 Portion of Energy Consumption by sub sectors (2002) [5]

Sugar is the main energy consumer in this sub sector and has an old technology. Average fuel consumption for each ton of sugar production is about 790 liters fuel oil. Therefore, the necessity of energy conservation activities in Iran's sugar industry is clear. In aggregate, it consumes 234210 equivalent cubic meter of fuel oil of natural gas, 29 equivalent cubic meter of fuel oil of LPG, 36 unit of kerosene, 42511 unit of gas oil ,and 784275 cubic meter of fuel oil.

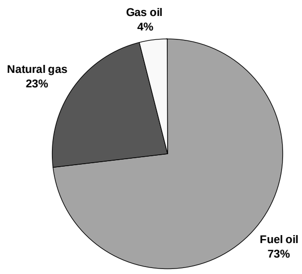


Figure 4 Fuel consumption portion in sugar industries (2002) [5]

The leading policy of government in recent years in order to replace natural gas instead of fuel oil as the first consumption fuel of industries caused a significant shift in the energy consumption patterns in industries in which 65% of total energy used by food factories was natural gas in 2004-2005.

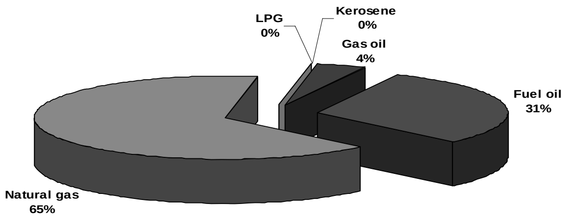


Figure 5 Quantity of energy carriers using in food production (004-005) [5]

The overall present situation of sugar industry in Iran is as follow:

Table 1 Present energy situation of sugar factories in IRAN in 2002 [5]

Total production (ton)	591242
Energy intensity (GJ/ton)	27
Saving potential in comparison with the average consumption in IRAN	1224128 GJ
	7.9%
Saving potential in comparison with the average consumption of the world	3735175.22 GJ
	24.6 %

Production of sugar has been changed during the last decade and has increased tremendously due to the rapid change of human demands.

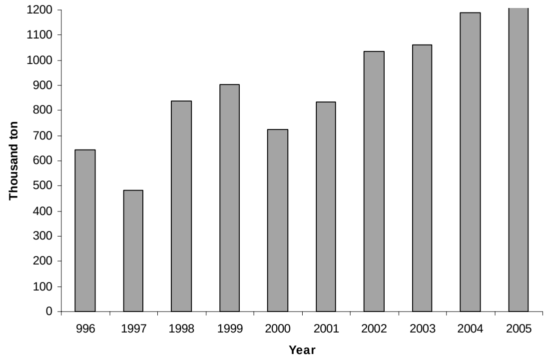


Figure 6 Amount of sugar production during last decade [6]

SEC is the specific energy consumption index and is evaluated for 36 individual firms and values are shown in Figure 7.

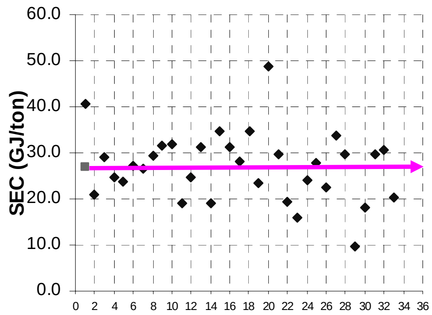


Figure 7 SEC index of different factories (2002) [5]

Due to the old machinery and inefficient use of technologies, energy intensity of factories is much higher than the current available technologies in the world.

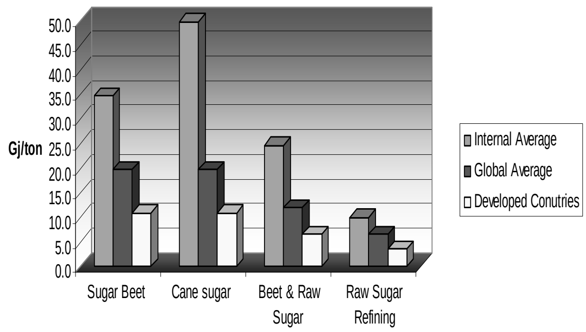


Figure 8 Energy intensity in sugar factories (2002) [5]

By comparing the value of energy intensity index between Iranian factories and average of world, a primary estimate of achievable saving potential of each firm will guide us toward better applied policies.

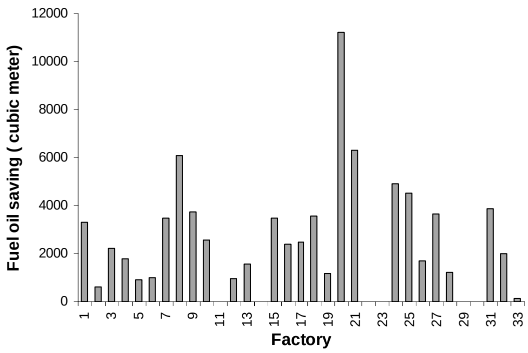


Figure 9 Energy saving potential of each factory in terms of fuel oil saving

3 Process descriptions

A simplified process flow sheet for sugar processing, as used in the case-studied sugar plant, is presented in Figure 10. After transportation, sugar beet is first cleaned and washed to remove soil, stones and organic matter from the beet. Cleaned and sliced beet is supplied to the extraction unit where raw juice is extracted. The subsequent pulp is dewatered by mechanical pressing, followed by thermal drying to produce dried pulp. Dried pulp is pelleted by the addition of molasses, in order to ensure cost-effective storage and transport. The extracted raw juice is purified using lime-milk in order to remove non-sugars. During the purification process, the carbonation slurry produced is concentrated in thickening filters. The rest is further concentrated to carbonation lime using rotary drum filters and/or filter presses.

Further processing takes place in a multiple-stage evaporator, which is of special importance for sugar processing, because medium-temperature vapors are generated and used for extraction, juice heating, crystallization and other operations requiring heat. The vapor needed to heat the first stage of evaporator is supplied from a boiler house.

Concentrated thick juice from the last evaporator stage is supplied to the multi-stage evaporating crystallization, where the dry solid content of the solution or the crystal suspension (magma), consisting of sugar crystals and the mother liquid, is increased. Crystallized sugar is recovered from the syrup by centrifugation, in screen-basket centrifuges. The mother syrup of the last crystallization stage is called molasses. White sugar, which leaves the centrifuges, is dried and stored in silos, waiting to be packed.

The process for the sugar production from cane is very similar to the above process and there some differences in the preparation and extraction step. Sugar is extracted from beet in the milling, diffusion end pressing sections while sugar is extracted from cane in the crusher and milling sections with water.

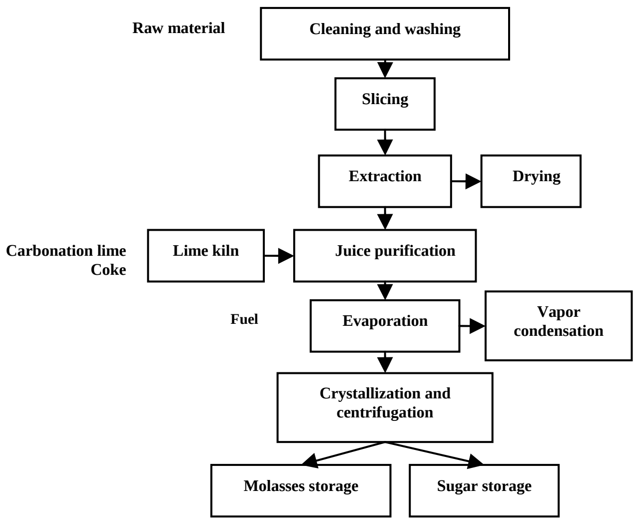


Figure 10 Schematic of Sugar production process

White sugar is produced from raw sugar in the following process

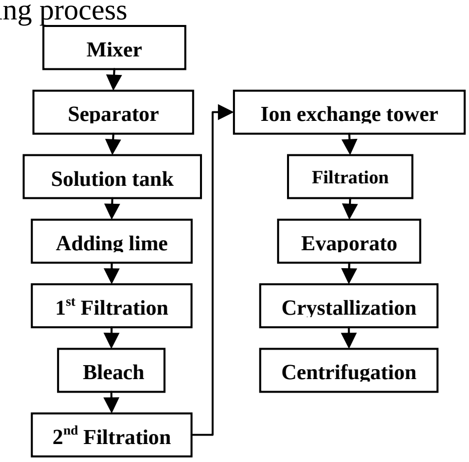
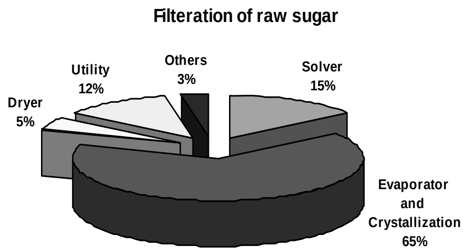


Figure 11 Schematic of production of white sugar from raw sugar

The energy demand in sugar processing is determined by four interlinked energy-intensive process stages: extraction, juice purification, evaporation and crystallization. The energy system is composed of a boiler house, multiple-stage evaporator, and a process heating subsystem.

A multiple-stage evaporator system is used in sugar processing, in order to improve energy efficiency. The crystallization process was found to be the biggest energy consumer of vapor extracted during evaporation.



(a)

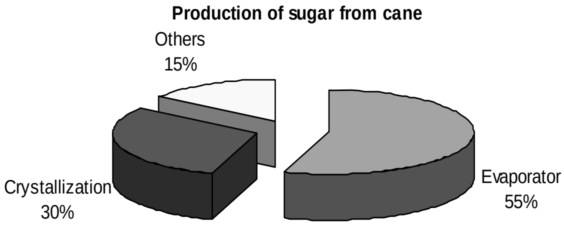


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Figure 12 Energy required by different process sections

4 Energy Auditing methodologies

Energy audits are the most comprehensive approaches to improving an existing system's energy efficiency. During 2004-2006, energy audits of sugar production units have been conducted in Iran. These audits can identify specific opportunities for improving energy efficiency and promoting the process efficiency. The energy auditing team does their job in two levels: primary and final auditing. At first, they study the historical consumption trends and technological information of the factory; identifying the potential of saving opportunities roughly and preparing the primary report. In the final stage they measure the electrical and thermal characteristics', plan the necessary experiments, calculate the intensity according to national standards for sugar energy usage. They provide mass and energy balance in different sectors, identify waste streams and find the solution in order to descend these wastes. Finally, the possibility studies and economical calculations are done and the final report will be prepared.

5 Results and Discussion

In Iranian factories, energy intensity of sugar production are 34.6, 49.8, 24.7, and 10 GJ/ton respect to different production processes like sugar beet, cane sugar, beet & raw sugar, and raw sugar refining respectively. Thus, the average energy intensity among all factories is 27 GJ/ton.

Fuel cost in total final sugar price in Iran despite of low fuel price is about 4.7% whereas corresponding value for European countries, which pay higher international price for their fuel is about 2.9%.

Due to the low internal price of energy, the energy consumption is huge and no logical behavior control the increasing trend. Currently, the government passed a rule and applied a financial mechanism which pushes the factories to reduce their energy consumption level. Factories that consume more energy than the determined index by the government must pay 20 percent extra for price of energy usage. The Energy Standard for the sugar from the point of electrical and thermal specific energy consumption is more rigid and may be categorized as: high energy intensive, medium energy intensive and low energy intensive processes. The government laws compelled the factories to consider these standards.

Therefore, the government can apply a multi step program in order to reach the final desired target (the average index of the world). Four steps can be arranged in which each provide a definite saving potential. In the first step, the determined index can be equal to the average energy intensity of the all factories in the country. This will provide the government 16.3 percent of energy saving equivalent to financial saving of 19.7 million $ in FOB prices. More than 40 percent of factories must change the process in order to reach the specified goal. The second applied index will be 150% of the average of total world which has 27 percent of energy saving, equivalent to 35.6 million $ and more that 70 percent of factories are covered in this step. In the third level, the index can be reduced to 125 percent of the average of total world and this will bring us 38 percent of saving, equivalent to 45.9 million dollar. 90 percent of all firms have to adapt their technological process in order to reach this index. Finally, the energy intensity of all factories must reach to the current average intensity of the world. This step has 54 percent of energy saving potential equivalent to 65.2 million $. It can be easily seen that all units have a deviation from the current index of the world.

The main reasons for this gap management problems, old machinery, and old production technology and cane & beet sugar content. In addition, it has been investigated that there is a large gap in raw sugar refineries between Iran and other countries.

Beside this achievable potential there some short term to mid term options that can be applied in individual factories with low investment cost and high rate of return. These solutions are investigated by energy auditing teams in all factories. Following the present methodology, they determine 561176336.3 cubic meter of natural gas thermal saving annually equivalent to 11700 million dollars per year and 23220627.15 KWh/year electrical saving equivalent to 1.2 million dollars annually in 17 plants.

5.1 Electrical saving potential

The major consumers of the electricity are motors and drivers. Using controllers on the fan's speed, appropriate use of electrical motors, and also utilizing high efficient motors will result in significant electrical saving. The amount of electrical savings is shown in the following figure.

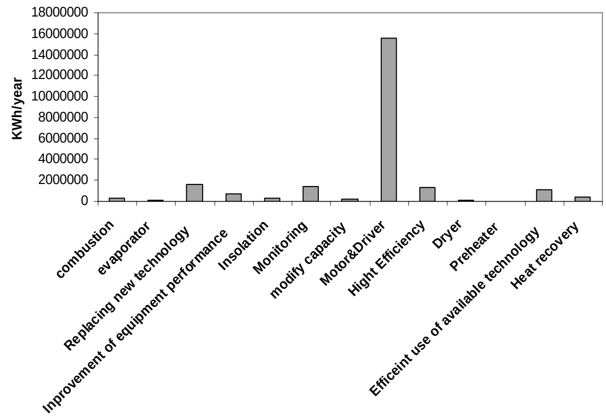

Figure 13 Electrical saving potential

5.2 Thermal saving potential

The major form of energy used in sugar plants is the thermal energy. The following potential are found in the sugar factories:

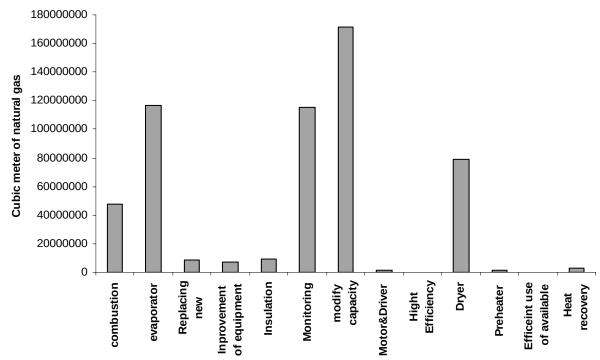

Figure 14 Thermal saving potential

- ✓ Replacing old technologies with new, efficient ones: replacing motors in the mills, CO_2 and cane pumps, steam furnace, water pump, and dryers to reach maximum efficiency, using ejectors instead of vacuum pumps, Convert shell and tube evaporators into plate and frame ones.
- ✓ Installing Monitoring and control equipments
- ✓ Improving insulation: including valves, pipes and tubes, and other connections.
- ✓ Heat recovery: from furnaces, evaporators, and boiler stacks.
- ✓ Improving combustion process: exact adjust of furnace performance, install gas analyzer on the output gas stream from boiler, install flow meters to calculate the input water to the boiler, correct the ratio of fuel to air at the inlet of the furnace
- ✓ Increasing the efficiency of evaporators: adding the additional facilities to increase the evaporator's efficiency, Increase the stages, Increase the concentration and temperature of input solution to first stage, Vacuum the last section of evaporators, correct the piping system for steam
- ✓ Using high efficient electrical motors
- ✓ Modify capacity
- ✓ Installing pre heaters for the input juice and air
- ✓ Modifying dryers
- ✓ Improvement of performance of other equipments: recycle the condense water to the boiler, avoid the steam leakage, Correct the operation of pumps and electro motors.

Due to the huge usage of steam applying cogeneration of heat and power which typically incorporates a steam boiler and a steam turbine will lead to reduce the waste.

5.3 Identification of utilization possibilities for waste and by-products

Several possibilities exist for utilizing waste from the sugar production process by the

selection of solutions that offer energy saving potentials.
One of the soil utilization options would be the production of marketable soil substrates by composting it with other agricultural waste products. Dewatered soil can be sold primarily to the landscaping industry and it is ideal for shrub planting, seeding or turf laying. All the separated soil can be used in productive applications. However, some of it must be returned to agricultural land in order to replenish stocks. Stones are also received with the crop. The case-studied plant recovers the stones and uses them for civil engineering, road repair and construction applications.
The organic matter can be used for the direct production of compost or for animal feed in the form of silage. Beet pulp remaining after the extraction of sugar can be used for direct animal feed or could be dried alone or combined with molasses.
Dried pulp in the form of pellets is mainly used as animal feed. A small portion of beet pulp is being used as a fibrous ingredient for human consumption. Some proposals have also been made to partly replace the cellulose from trees in paper production, using dry beet pulp. Beet pulp cannot be used as a direct substitute for wood since it has lower cellulose and lignin contents. However, instead of completely replacing the cellulose from trees with beet pulp, it could be employed as an ‘‘organic filler’’. The paper, which obviously cannot reach a whiteness comparable with that of paper obtained from pure cellulose, can, however, be normally utilized for printing, photocopies, etc.
In the sugar industry, approximately 90% of molasses is used for fermentation. Molasses is also suitable as livestock feed because of its sugar and crude protein contents.
Carbonation lime is mostly used in agriculture for soil pH correction, significantly reducing the volume of limestone that would otherwise be mined and crushed for agriculture and other lime markets. Most recently, lime has also been used for mushroom production.
Hot water from the sugar plant could be carried to greenhouses to maintain temperatures for growing vegetables. Thus, hot water that would otherwise be destined for cooling towers can thereby put this low-grade heat to a productive use. Wastewater from the case-studied sugar plant can be disposed off by sprinkling or surface irrigation to make use of the contained water, fertilizer or nutrients, to grow autotrophic plants.
Carbon dioxide, a by-product from the steam boiler, could be pumped into the greenhouse where it would be utilized by the plants rather than being released into the atmosphere. It can also be used as carbonation gas for purifying juice.

6 Conclusion

Energy minimization in the sugar plant is one of the most important issues within the context of sustainability. The aim of this study was to determine energy situation in sugar industry in Iran and the possible energy and financial saving potentials. Energy auditing is a powerful tool, which has been successfully and effectively used in the design and performance evaluation of energy-related systems.
The main conclusions drawn from present study may be summarized as promoting recycle economy, facilitating technological progress, reduce consumption, and protect the environment. Applying standards will help the industry to reduce energy costs in coming years too.

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